In-Network Fusion for High Interference Signal Detection within CBRS Band

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***Abstract*—In this paper, we present an advanced signal detection framework for shared spectrum. The primary goal is to detect of radar pulses and 5G signals, ensuring seamless coexistence in shared spectrum environments, particularly within the Citizens Broadband Radio Service (CBRS) band. We propose a novel in-network fusion-based solution which relaxes the Federal Communications Commission (FCC) requirement of achieving a radar detection accuracy of at least 99% for a signal-to-interference-noise ratio (SINR) ≥ 20 dB to SINR ≥ 0 dB. This adjustment enables a robust detection of radar pulses even in the presence of interfering 5G signals which can introduce up to 20 dB more interference. By utilizing emulated digitized radar signals for spectrogram analysis and adopting our in-network fusion-based approach, we demonstrate 99% signal detection for SINR ≥ 0 dB.**

I. Introduction

The increasing demand for wireless connectivity and the scarcity of available spectrum have led to the adoption of shared spectrum access models, such as the Citizens Broadband Radio Service (CBRS) band. This band is a critical resource that enables the coexistence of multiple communication systems, including radar and 5G networks. While this shared spectrum approach enhances spectrum utilization, it also introduces challenges, such as interference between incumbent radar systems and new communication technologies. Efficient detection and mitigation of interference are essential to ensuring reliable operation and compliance with Federal Communications Commission's (FCC's) regulations of achieving detection of 99% of radar pulses in signal-to-interference-noise ratio (SINR) 20 dB [1] at the environmental sensing capability (ESC) sensor. The state-of-the-art (Waldo [2], DeepRadar [3] and adYoloLet [4]) use the variation of the widely used object detection based machine learning algorithm you only look Once (YOLO) to detect radar signals in the CBRS band from only the spectrograms at the ESC sensor (CBRS hierarchy is presented in Fig. 1). In this paper, we extend the state-of-the-art by proposing a machine learning based approach which strategically fuses extracted features from both in-phase and quadrature (I/Q) data and spectrograms to meet the FCC's 99% signal detection requirement even for 0 dB SINR. Overall, the contributions are listed below:

- We propose custom convolutional neural network (CNN) and artificial neural network (ANN)-based feature extractors to extract the numerical and visual features from the pre-processed I/Q data and spectrograms streams, respectively.
- We develop a in-network fusion framework that processes and combines spectrogram and pre-processed I/Q data directly within the architecture. By eliminating external pooling and synchronization steps, this end-to-end design accelerates training, improves inference efficiency, and enhances detection accuracy for CBRS band interference.

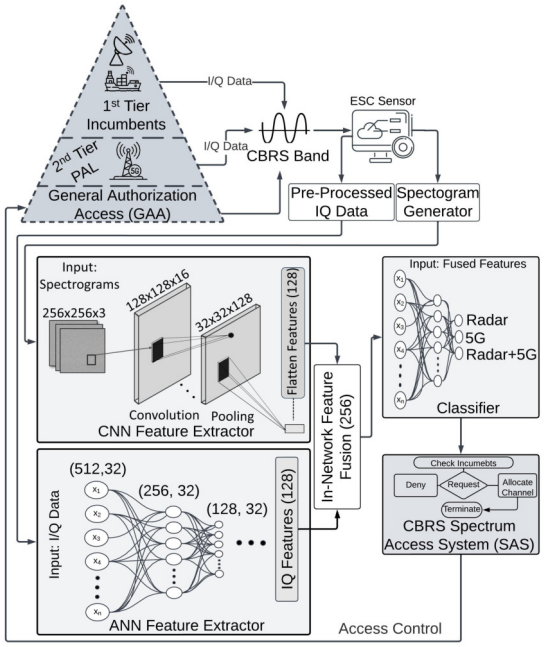

Fig. 1: Proposed in-network fusion-based radar and 5G signal detection for CBRS band along with the hierarchical structure of the shared spectrum access.

- We evaluate the proposed approach on a home-grown synthetic dataset simulating real-world radar pulses overlapped with the 5G signals at SINR level as low as 0 dB.

II. Proposed Framework and Evaluation

In Fig. 1, we show the step-by-step details of our proposed in-network fusion-based solution. At the ESC sensor, the I/Q data is used to generate the dual-streams of our framework. We use the first stream to generate spectrograms to transform the signal to time-frequency domain. The second stream is passed through a pre-processing step where a refined I/Q data stream is generated. Both these data steams are passed through feature extractors: (a) the generated spectrograms are then fed into a CNN feature extractor to identify class-specific features associated with the input data, and (b) the pre-processed I/Q data is processed by an ANN feature extractor, designed to capture complementary numerical features from the raw signals. Both feature extractors output 128 features each, which are then concatenated at the next layer of the network. Unlike traditional concatenation methods [5], the features in our framework are fused directly within the network. This approach ensures synchronization between the extracted features and accelerates the training process by maintaining alignment across modalities. The concatenated features are subsequently

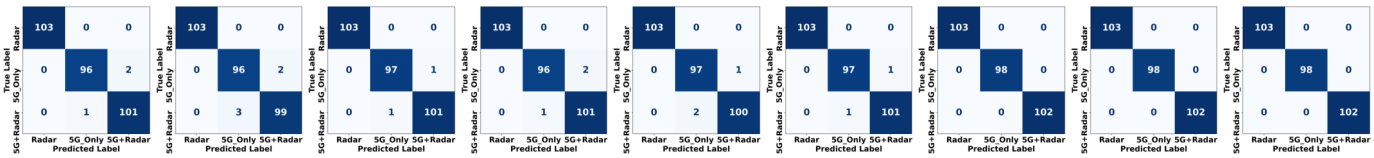

Fig. 2: (a)-(c) SINR 0 dB: I/Q data only {3}, spectrogram only {5}, and in-network fusion {2}. (d)-(f) SINR 10 dB: I/Q data only {3}, spectrogram only {3}, and in-network fusion {2}. (g)-(i) SINR 15 dB: I/Q data only {0}, spectrogram only {0}, and in-network fusion {0}. The corresponding total number of misclassifications are given within braces.

passed through a classifier consisting of fully connected layers to determine whether the input sample originates from `radar` pulses, `5G` signals, or a combination of both (`radar + 5G`). Once the classification is complete, the system communicates its decision to an FCC-approved spectrum access system (SAS). Based on the classification and the priority levels defined by the SAS, access to the spectrum is either granted or denied to the requesting user.

Dataset Description: We generate a synthetic I/Q dataset using MATLAB's Communication, Array Processing, and 5G Toolboxes. The simulation involves creating a 5G physical layer signal by placing a base station, multiple user equipments, and a radar system at specific 3D locations. Both 5G communication and radar transmissions propagate through a multipath fading channel and are received at the base station's 2×2 uniform rectangular array (URA) antenna. The dataset features a radar signal with different SINRs (ranging between 0 dB to 20 dB) relative to 5G and noise levels, sampled at 61.44 MHz with a center frequency of 3.6 GHz, modeling the interaction between radar and 5G signals in a realistic shared spectrum environment. The dataset contains ~ 1500 generated signals from three categories: (a) radar pulses only, (b) 5G signals only, and (c) radar pulses overlapped with 5G signals.

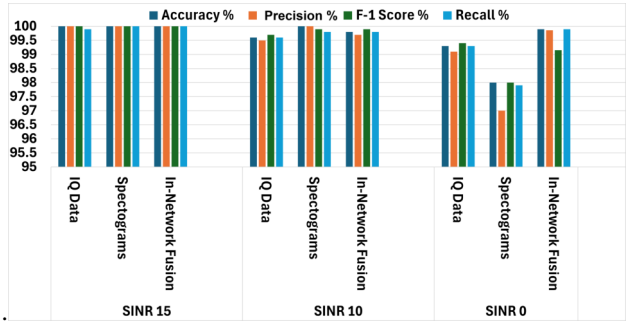

Fig. 3: Comparison of in-network fusion solution with the single stream solutions.

Experimental Results: Our evaluation results are presented in Fig. 3 to demonstrate the robustness of the proposed approach under varying SINR levels. We also conduct an ablation study by individually training two separate networks (ANN for I/Q data and CNN for spectrograms) and combining their features through our in-network fusion mechanism. At SINR $\geq$ 15 dB, both the ANN and CNN models achieve excellent performance, with metrics reaching 100% for accuracy, precision, recall, and F1 scores. At SINR = 10 dB, the ANN achieves 99.6% accuracy and a 99.6% F1 score, while the CNN performs slightly better with a 99.8% F1 score. The fusion framework surpasses both, achieving 99.8% precision and 99.9% recall, as shown in Fig. 3. These results indicate that the fusion framework consistently leverages complementary features effectively.

For the high interference scenario, i.e., SINR = 0 dB, individual networks show performance degradation, with CNN accuracy reducing to 98%. However, the fusion framework demonstrates remarkable robustness, achieving 99.9% accuracy and a perfect F1 score of 100%. The confusion matrices, in Fig. 2, further illustrate the proposed fusion framework's ability to minimize misclassifications, even under high interference scenario of SINR = 0 dB. Overall, the fusion framework outperforms individual networks across all SINR levels, achieving an average accuracy of 99.9% compared to 99.63% (ANN) and 99.33% (CNN). This demonstrates the proposed framework's effectiveness and reliability for spectrum-sensing applications in high interference environments.

III. Conclusions & Discussion

In this paper, we present a novel fusion-based framework for signal detection for enabling effective coexistence in shared spectrum environments, particularly within the CBRS band. By leveraging advanced machine learning techniques, the proposed framework yields to high performance even for 0 dB SINR surpassing the FCC's requirement by 20 dB. The fusion of spectrogram and I/Q data streams opens up new avenue for detecting interference signals within such shared bands. Experimental results validate the framework's ability to detect radar pulses with an accuracy of over 99% at SINR levels $\geq$ 0 dB. Further research will explore real-time deployment of the system with software defined radios and extending the system's capabilities to other shared spectrum scenarios.

Acknowledgement

The authors gratefully acknowledge the support from funding from the US National Science Foundation (CNS 2229444).

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